Technische Universität München

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Knowledge-based pattern recognition and visualization of error logs of time-based engine sensor data: Requirements engineering and tool-support

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Overview

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“Knowledge-based pattern recognition and visualization of error logs of time-based engine sensor data: Requirements engineering and tool-support”

1. **Introduction**
2. **Research Questions**
3. **Tool-support**
4. **Roadmap**

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Introduction

IAV GmbH
Ingenieurgesellschaft Auto und Verkehr

Type	Limited liability company: GmbH[1]
Industry	Automotive industry[1]
Founded	Berlin, Germany (1983)[1]
Founder	Prof. Dr. Hermann Appel
Headquarters	Berlin, Germany
Number of locations	16 operations across Germany, several Subsidiaries
Area served	Worldwide
Key people	Kurt Blumenröder, President, CEO;[2] Michael Schubert, President, CFO[2]
Services	Powertrain, Electronics and Vehicle Development
Revenue	595 million Euro (2013)[1]
Number of employees	5,700 worldwide (2013)[1]
Website	IAV.com

Introduction

Series engines

Diesel engines

Gasoline engines

Electrical, hybrid engines

Error data

Error data

Error data

Supervision and support of series engine production

Error analysis

Root-Cause identification

Error-handling procedure

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Context

- On board – data logger in Engine Control Unit
- Data logger generates measured data files (MDF-Format) when a registered Event is detected.
- Measured data files consist of dynamic (time-based) and static measured values.
- Time-based measured values differ in recording duration and sampling rate.
- Different Events have different measured channels. Several causes could lead to one Event.
- Measured data files helps to identify Root-Cause.

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MDF–Data (Measurement Data Format)

Raw data

Static measured value

- Engine start temperature: [70]
- Mileage: [1234]
- Gear number: [3]
- Current speed: [130]
- ...

Time series

Dynamic measured value

- Round speed: [1000; 900; 800; 700 ..., 0]
- Time_RoundSpeed: [-3; -2; -1; 0; 1; 2; 3]
- Cylinder pressure: [20,2; 19,8; 12,3; 15,5;...]
- Time_CylinderPressure: [-1,0; -0,5; 0; 0,5;..]
- ...

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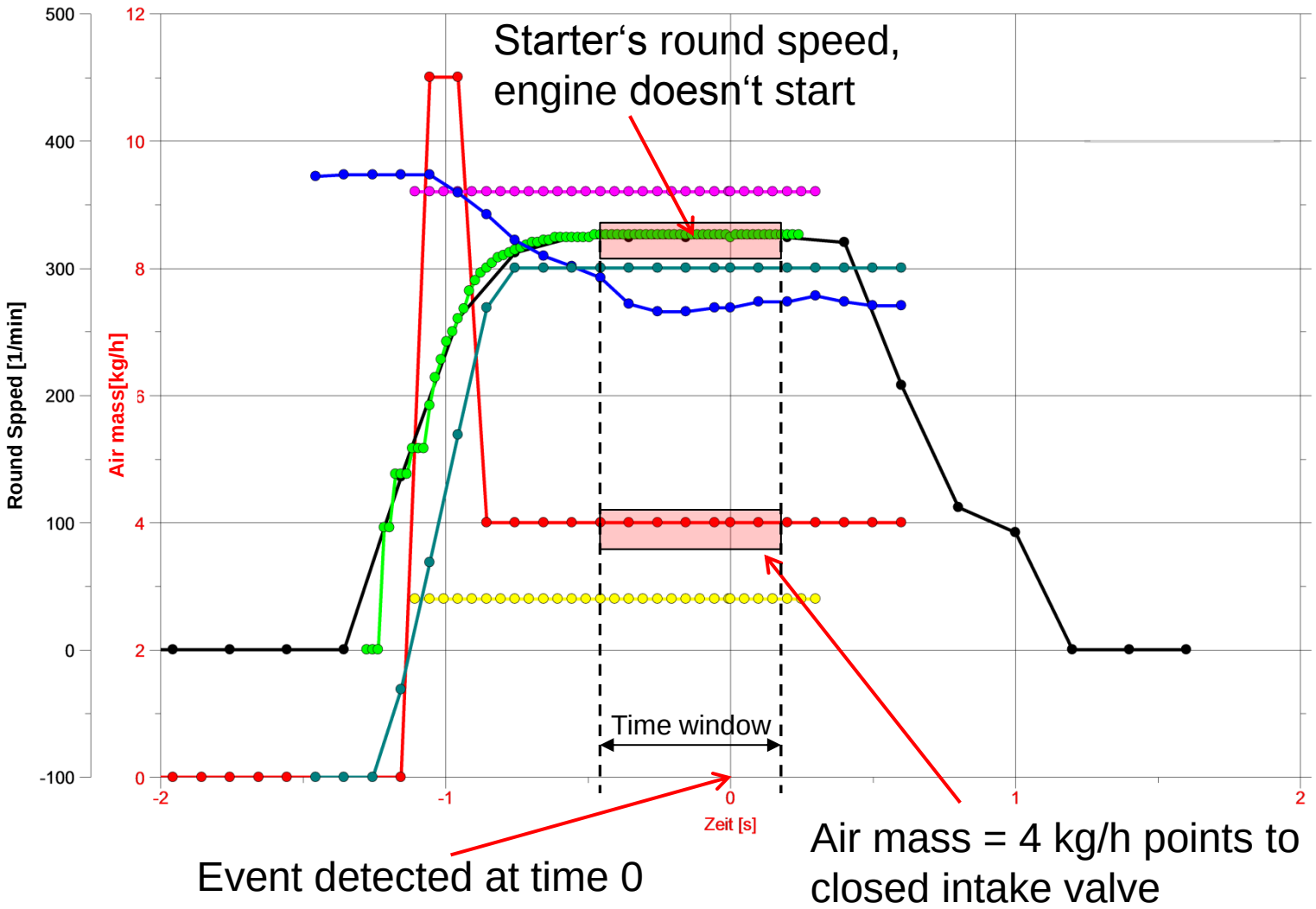
Error pattern - Example

Event: Engine does not start!



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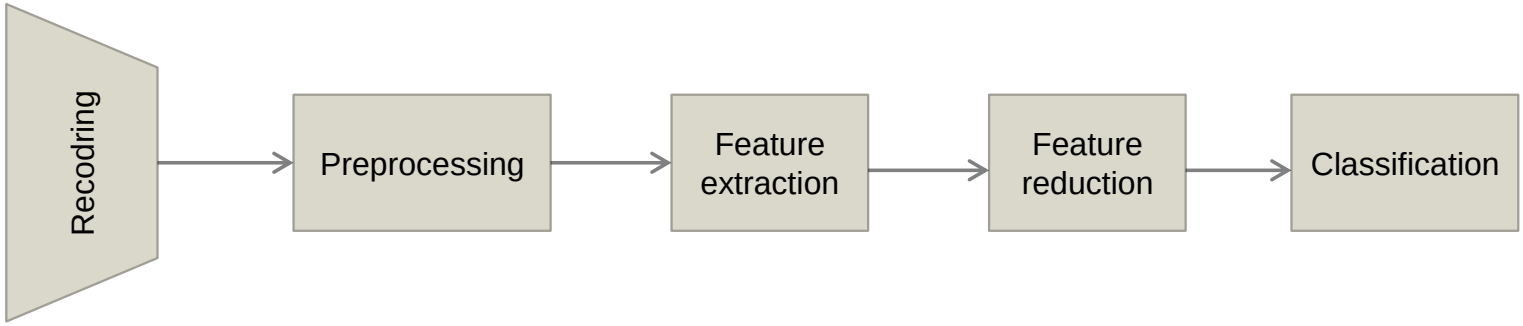
Error pattern discovery

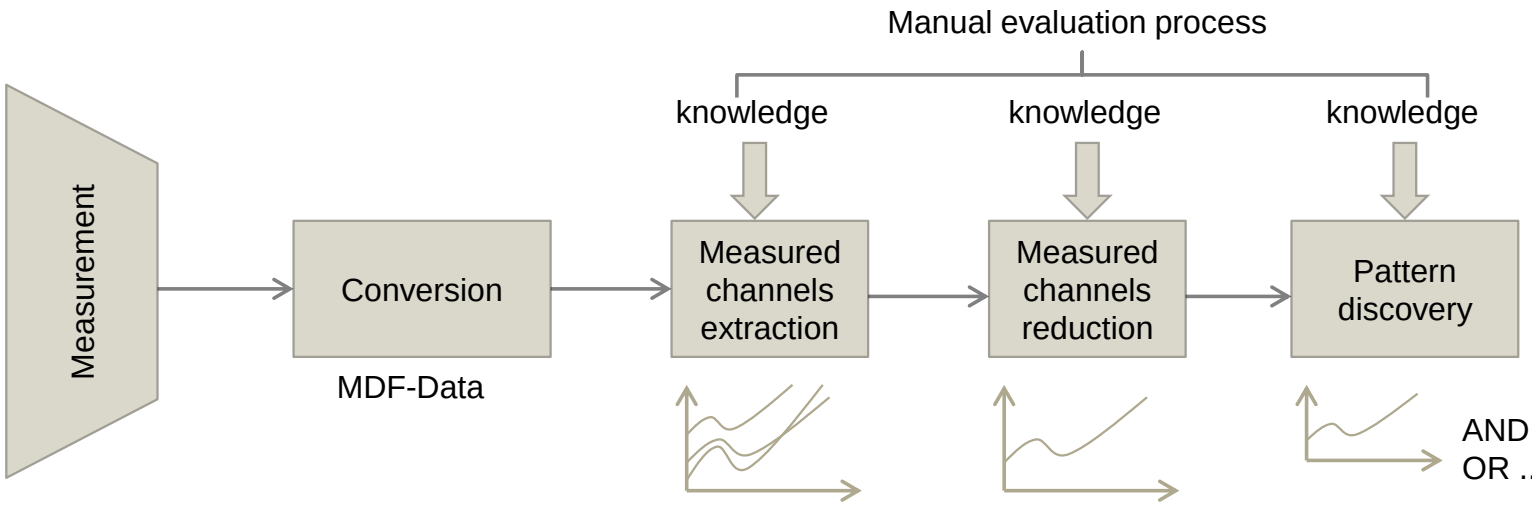
General pattern recognition/discovery: Speech recognition, Optical Character recognition, Image analysis...



Abstract

Knowledge-based pattern discovery: Engine error pattern.

Concrete



AND other Conditions...
OR ...
...

Raw data in ECU

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Research Questions

1. **Research Question 1: Which phases does a knowledge-based pattern discovery process contain?**
   - Iterative approach
   - Based on pattern recognition/discovery in other domain

2. **Research Question 2: How to define a pattern in the context of engine error data?**
   - Static condition
   - Dynamic condition: time series pattern definition.
   - Logical connectives: Negation, Conjunction, Disjunction.

3. **Research Question 3: How can a tool support the recognition of time series pattern of engine error data?**
   - Compare two signals (two time series):
     - time series matching
     - time series similarity search
   - Pattern matching degree: How many percent does case X match pattern Y?

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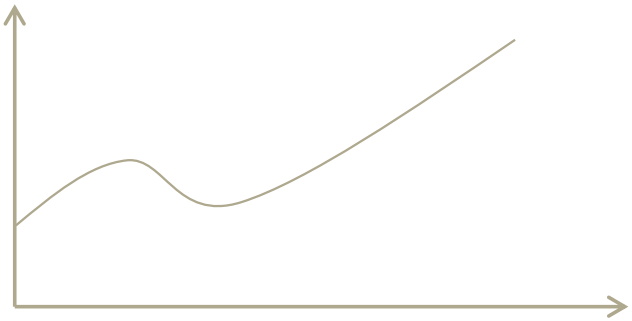
Tool-support

1. **Pattern discovery**
   - Tool supports the manual evaluation
     - Export data
     - Visualization of measured channels

2. **Pattern definition**
   - Static Condition: Temperature > 70°C…
   - Dynamic Condition: Time series pattern (signal pattern) definition:
     - Basic component: Slope, Period signal,…
     - Nodes and Interpolation
     - Use available data



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Tool-support

3. Pattern recognition

- time series matching:
  - Consider particular features of engine error data
  - Euclidean Distance: n = 2; time series x, y; length M

$$d_{L_n}(x,y) = \left(\sum_{i=1}^{M} (x_i - y_i)^n \right)^{\frac{1}{n}}$$

  - Discrete Fourier Transformation

$$d_{FC}(x,y) = \left(\sum_{i=1}^{M/2} (\hat{x}_i - \hat{y}_i)^2 \right)^{\frac{1}{2}}$$

- Matching degree:
  - Fuzzy Logic
  - Compare a threshold value with d_{FC}, d_{L_2}

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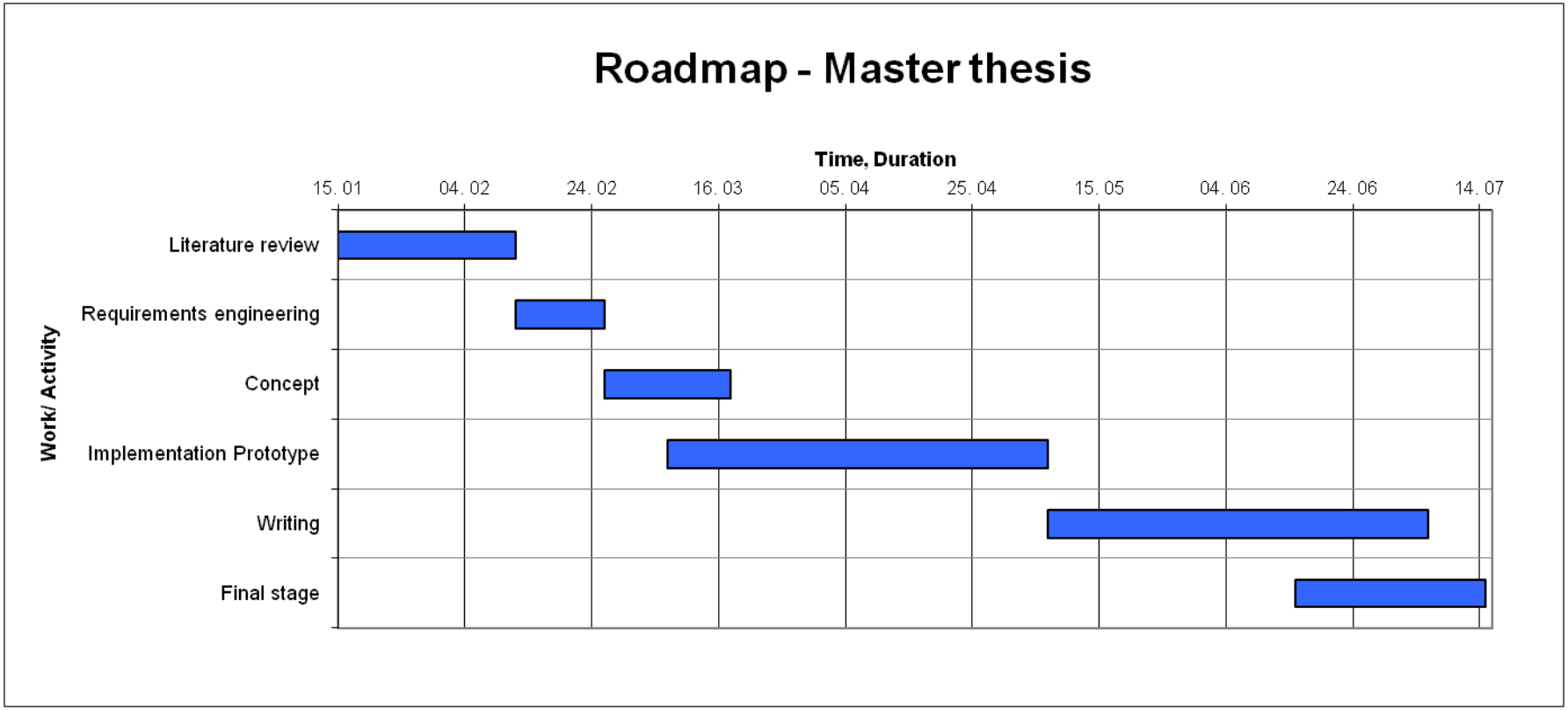
Roadmap



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Thank you for your attention!

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